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NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

NASA-16702 (July 2003)
NASA - KSC
Superseding NASA-16702
(March 2003)

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NASA-16702 (July 2003)
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SECTION 16702

OUTSIDE CABLE PLANT - FIBER
07/03

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NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This section covers requirements for the fiber cabling system of the outside cable plant. Accordingly, this section should be tailored carefully to suit project conditions and to meet project requirements.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: The following references should not be manually edited except to add new references. References not used in the text will automatically be deleted from this section of the project specification.

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The publications listed below form a part of this section to the extent referenced. The publications are referred to in the text by basic designation only:

JOHN F. KENNEDY SPACE CENTER (KSC)

79K28125 (1996) Fiber Optic Cable Specification for Kennedy Space Center

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2002) National Electrical Code

1.2 GENERAL REQUIREMENTS

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NOTE: Review submittal description (SD) definitions in Section 01300, "Submittals," and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control. Include a columnar list of appropriate products and tests beneath each submittal description.

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1.2.1 Scope

This section covers the requirements for fiber optic cables and associated components. The fiber optic cable shall consist of optical fibers, strength member (or members), filling compound and jacketing. The associated components shall include optical fiber connectors, fiber optic terminal assemblies, terminal bay cabinets, and splice closures as indicated. The fiber optic cables shall be installed in inner duct in the existing cable duct and manhole system. The fiber optic terminal equipment shall be located in existing facility buildings.

All cables shall be installed and spliced as specified herein and on the drawings.

Unless otherwise specified, all references in Section 16702 to cable shall be deemed to mean fiber optic cable.

1.3 SUBMITTALS

The following shall be submitted in accordance with Section 01330, "Submittals," in sufficient detail to show full compliance with the specification:

SD-03 Product Data

Optical Fibers (uncabled)
Fiber Optic Cable
Splice Organizers and Enclosures
Splice Trays
Encapsulating Compound
Pre-Connectorized Cable Assemblies
Connector Feedthrough Adapter
Fiber Optic Terminal (FOT) Bay Cabinet
High Density FOT Cross-Connect System

SD-06 Test Reports

Provide a Fiber Cable acceptance test plan at least 30 days prior to testing.

Installed Fiber Cabling Acceptance Test Plan

Test Results for Optical Fibers (uncabled)
Fiber Optic cable (reeled and installed)
Pre-connectorized Cable Assemblies

SD-07 Certificates

Provide a Certificate of Compliance for each of the following items:

Optical fibers (uncabled) as defined by paragraph 8.1 of Specification 79K28125, Revision K.

Fiber Optic Cable as defined by paragraph 8.2 of Specification 79K28125, Revision K.

OFNR Cable NEC Fire Rating.

OFNP Cable NEC Fire Rating.

PART 2 PRODUCTS

2.1 CABLE

The cable shall be manufactured in accordance with the requirements of KSC Specification 79K28125, and as indicated herein. The cable manufacturer must provide a warranty on the cable for a period of at least five (5) years. Unless otherwise shown on drawings, all cables routed in buildings for a distance of greater than 15 m50 feet shall transition to riser or plenum rated cables and conform with the OFNR/OFNP cable requirements of NFPA 70, Article 770. All contractor provided fiber shall be of the same type, specification, and manufacturer. Changes to the KSC Specification are indicated below.

2.1.1 Quantities and Colors of Fibers and Buffer Tubes

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NOTE:
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Quantity of fiber and colors of buffer tubes will be defined by the project requirements.

[Sheet 7, paragraph 4.2.7.2, entitled, "72-Fiber Cable", change to, "The fiber cable shall contain 72 SM fibers, with a cable core configuration comprised of at least 6 loose buffer tubes each containing a 12-fiber bundle."

Sheet 7, paragraph 4.2.7, entitled, "The Number of Fibers Per Tube Per Cable", add a fourth type of cable, a 12-fiber cable and add paragraph 4.2.7.4 as follows:

"4.2.7.4 The 12-fiber cable shall contain 12 SM fibers with a cable core configuration comprised of 2 loose buffer tubes. These

buffer tubes shall contain 6 SM fibers in each buffer tube."

Sheet 7, renumber existing paragraph 4.2.7.4 to, "4.2.7.5".]

2.2 CABLE IDENTIFICATION SYMBOL CRITERION

The first of three lines on the ID symbol shall employ the following seven (7) characters:

First, Second, and Third Characters: The first, second, and third characters (from left to right) shall denote the number of active optical fibers in the cable.

Fourth Character: The fourth character shall be a slash.

Fifth, Six, and Seventh Characters: The fifth, sixth, and seventh characters shall denote optical transmission windows which the optical fiber can support. These windows are defined herein as follows:

a. The fifth character shall be an "A" or an "O". The "A" denotes a window at a wavelength of 850 nanometers (nm), with an attenuation of 4 dB/km and a bandwidth of 800 MHz-km. The character shall be an "O" if these requirements are not met.

b. The sixth character shall be a "B" or an "O". The "B" denotes a multi-mode window at a wavelength of 1,300 nm, with an attenuation of 1 dB/km and a bandwidth of 1 GHz-km, or a single mode window with an attenuation of .5 dB/km. The character shall be an "O" if these requirements are not met.

c. The seventh character shall be a "C" or an "O". The "C" denotes a multi- or single mode window of a wavelength of 1,550 nm, with an attenuation of 0.5 dB/km. The character shall be an "O" if these requirements are not met.

The two lower lines of the cable ID symbol shall indicate multi-mode or single mode fibers, cable number and fiber count.

Example: 072/OBC Identifies the number of optical fibers (72) and the optical transmission window (as indicated above).

FM50: 141-200: Identifies Multi-Mode Fiber Cable 50 with Fibers 141 through 200.

and FS50: 25-36: Identifies Single Mode Fiber Cable 50 with Fibers 25 through 36.

2.3 SPLICE ORGANIZERS AND ENCLOSURES

The single mode or multi-mode fibers shall be fusion spliced with a protective sleeve covering (buffer tubing) and stored in an organizer. For each fiber, a minimum of 18 inches of spare coiled fiber in buffer tube is required. The single mode fibers shall be spliced last in the splice tray.

All splices shall be housed in a "closure within a closure" scheme, in which the area between the inner and outer closure is totally filled with a re-enterable encapsulating compound.

The inner closure shall house and support a splice tray organizer which holds in-place, up to 12 splice trays. The splice trays shall house a splice block for protected fusion splices and hold 12 or 24 splices. The tray shall be large enough to route the fibers before and after each splice such that there are no detrimental effects to the signal properties at the wavelengths specified for the fiber. Each splice tray shall have its own cover.

The outer closure shall be suitable for a straight, butt, or branch splice and provide a protective housing made to receive an encapsulating compound. The splice case shall be made of thermoplastic, thermoset, or stainless steel material, with structural members as part of the mold (i.e., ribs or waffle structure). The encapsulating compound shall be re-enterable and shall not alter the chemical stability of the closure or any cable part. It shall be fast curing and adhere to surfaces throughout its expansion. The encapsulating compound shall act as a moisture block and shall be safe to the touch and contain no Isocyanates. Dry encapsulant shall not be used. End plates shall be factory drilled to fit the cable(s) outer diameter. AMP and Siecor (or equal, as approved by the Contracting Officer) are suppliers of approved splice cases.

2.4 PRE-CONNECTORIZED CABLE ASSEMBLY

The Contractor shall supply a factory assembled pre-connectorized cable assembly to interface with the patch panel bulkhead feed-through receptacle for each terminated fiber. The fiber in the pre-connectorized cable assembly shall be manufactured by the same manufacturer as in the multi-fiber cable. Both the cable assembly connector and the bulkhead receptacle shall be manufactured by the same manufacturer. The jacket for the assembly shall be a single fiber 900 micrometer tight buffered cable, riser rated as OFNR cable by the NEC. Contractor shall supply and install dust caps for all terminated fibers.

The connector/cable interface on both the single and multi-mode assemblies shall withstand a tensile force of 25 pounds.45 kg without detrimental affects on the optical dB loss characteristics.

Before the pre-connectorized cable assemblies are shipped to KSC, a Contracting Officer's representative may be required to visit the assembly and polishing site to inspect the assembly and quality control procedures, as well as random samples of the finished assemblies. If this is done, test requirements as indicated in other portions of this specification shall be verified at the same time.

2.4.1 Multi-Mode Cable

The multi-mode connector and bulkhead assembly (coupler) used to terminate and test the fibers shall be the equivalent of the AT&T enhanced multi-mode ST connector and coupling. The coupling shall be made of metal and shall

be the bayonet/flange type. The connector shall have a metal housing and a zirconia ceramic ferrule. The connector shall be PC polished finish and be terminated on a three (3) meter length of multi-mode fiber jacketed as a single fiber cable. Each connector half shall exhibit a loss of 0.5 dB or less. Additional approved manufacturers include 3M and Porta Systems.

2.4.2 Single Mode Cable

The single mode connector and feedthrough adapter (coupler) used to terminate and test the fibers shall be the equivalent of the AT&T enhanced ST connector and coupling. The coupling shall be made of metal and shall be the bayonet/flange type. The connector shall have a metal housing and a zirconia ceramic ferrule. The connector shall be PC polished finish and terminated utilizing heat cured epoxy on a three (3) meter length of single mode fiber jacketed as a single fiber cable. Each connector half shall exhibit a loss of 0.5 dB or less. The return loss for each connector shall be -30 dB or better. Additional approved manufacturers include 3M and Porta Systems.

2.5 LOOPBACK JUMPER BUNDLE ASSEMBLIES

Jumper bundle assemblies shall be used to perform loopbacks of fibers within the CXT Buildings, as part of the High Density Cross-Connect System. They shall consist of either single mode or multi-mode optical fibers, having the same specifications as the outside plant optical fibers described above. The jumper bundles shall consist of six (6) individual optical fibers having 900 micron jacketing material. Each bundle shall contain either six (6) single mode fibers or six (6) multi-mode fibers (fibers of different types shall not be mixed within jumper bundles).

The jumper bundles shall not contain connectors. All loopbacks of fibers shall be performed using a re-enterable mechanical splice as described in other sections of the specification.

Fibers within each jumper bundle shall be color coded using the same scheme as the outside plant fibers, i.e., they shall have the colors blue, orange, green, brown, slate, and white.

Jumper bundle assemblies shall be cut to necessary length from standard sized cable reels.

2.6 FIBER OPTIC TERMINAL ASSEMBLIES

All cable terminations within buildings other than the cross-connect buildings shall be made in fiber optic terminal assemblies. Fiber optic terminal assemblies shall be the pre-assembled "Optima Instrument" chassis and associated rack-mounting hardware manufactured by the Optima Enclosures, or equivalent.

2.6.1 Splice Trays/Cable Assembly Splicing

To facilitate the transition between outside plant cable and the pre-connectorized cable assemblies, the fibers shall be fusion spliced and protected with a heat shrink protective tubing slid over the splice. The

splice shall be held in a splice tray large enough to route fusion splices. The splice block shall be affixed in a splice tray large enough to route fibers before and after each splice, such that there are no detrimental effects to the signal properties at the wavelengths specified for the fiber. Each splice tray shall have its own cover. The splice tray shall be positioned in the fiber optic terminal assembly as indicated on drawings, and provide a minimum of 18 inches of spare coiled fiber in buffer tube in the patch panel before the splice tray. Attenuation of the fusion splice shall not exceed 0.2 dB.

2.7 FIBER OPTIC TERMINAL (FOT) BAY CABINET

The FOT cabinet in the VABR, shall be Optima Enclosure's "Optima Vertical Cabinet", Model No. R Series, or approved equal. The cabinet's frame shall consist of vertical and horizontal tubular aluminum extrusions, with a minimal wall thickness of .150 inches. Front to rear aluminum extruded corners shall be at least .125 inches in thickness. Rear door, top panel, and side panels shall be a minimum of 18 gauge steel. Cabinet shall be provided with 14 gauge steel, .281 inches punched panel/chassis mounting rails permitting recessed installation of equipment. Cable entry and exit holes shall be placed as shown on drawings. Dimensions of cabinet and associated cabinet hardware are as shown on drawings.

Remove side panels of new and existing FOT's for adjoining cabinets, unless otherwise indicated on drawings. Cabinet shall be gray in color. Quantities and sizes are as shown on drawings.

Optima accessories required for FOT cabinets:

a. Connection Kit HW-67 for adjoining cabinets.

b. Doors: Solid rear door, typical, Model No. D-7724nn Plexiglass front door, typical, Model No. 2D-7724nn-K "nn" is replaced by RH or LH, depending on location. Specific door ordering information is indicated on drawings.

Additional approved manufacturer of FOT cabinets and accessories include Great Lakes Case and Cabinet Company, Inc., of Edinboro, Pennsylvania.

2.7.1 12-Fiber Termination Panel

The 12-fiber termination panel shall be Siecor WIC-12, or approved equal. The termination panel shall be mountable on a plywood backboard. It shall contain removable splice trays capable of housing pigtail fusion splices with heat shrink protective sleeves. It shall contain a connector panel capable of terminating all fibers.

2.8 HIGH DENSITY FOT CROSS-CONNECT SYSTEM

High density FOT bays shall be used in the CXT Buildings only. The high density bays shall be capable of terminating no less than nine (9) 144-fiber cables in one 7 foot bay. The bay shall consist of up to nine (9) individual splice modules, each module having the capacity to terminate 144 outside plant fibers.

The high density bay shall include all necessary accessories to allow the routing of cross-connect jumpers, both within the bay and to adjacent bays within the same line-up.

The following are acceptable manufacturer's of high density bays: ADC, AT&T, Porta Systems, and 3M. The following information is provided in order to describe other products available from the manufacturers listed above, which also conform to the specifications of the high density cross-connect frames.

AT&T Network Systems: The LGX fiber optic distributing frame and LDS (Lightguide Distribution Shelves) are used to create high density fiber frames. In order to terminate the required 144 fibers in each LDS, the LSS1U-144 Lightguide splice shelf shall be used. Up to nine (9) of these units may be placed in one 7 foot bay.

Porta Systems: The Fiber Optic Connection Universal System (FOCUS) Fiber Distribution Frame (FDF) is used with the Universal Housing in order to create the high density fiber cross-connect bays. The universal housings shall be equipped with six (6) "Maximum Density" splicing shelves, which contain 28 splices each. Up to nine (9) housings may be located within one 7 foot bay.

3M: The 2400 Series High Density Fiber Cross-Connect System provides rack mounted high density cross-connect capability in a 23" x 7' rack. Five cross-connect cabinets (Model 2430) shall be mounted in a standard 23" rack. Each cabinet shall contain 24 high density connector cards (12 each of Model 2411 and Model 2413). Twelve (12) connectors (Model 2401) shall be furnished and installed on each connector card. The connectors shall function as the re-enterable mechanical splices for the 3M cross-connect system.

Certain elements shall remain common to the cross-connect system, regardless of the cross-connect manufacturer selected. These shall include, but not necessarily be limited to to the following: (1) top, side and rear jumper routing channels and/or troughs which allow manageable routing of jumpers between splice locations; (2) rear doors; (3) necessary hardware to secure frames to floor; (4) cable clamps which secure outside plant cables to the splice frames; (5) all necessary tools required to perform the mating/remating of the mechanical splice, and (6) all necessary labeling kits in order to adequately label the number of each fiber which terminates in the CXT's. All of these elements shall be provided with the high density cross-connect frames, regardless of which manufacturer or vendor furnishes the cross-connect system. These elements may or may not be furnished as an integral part of the vendor's cross-connect system, i.e. jumper routing troughs may require additional items to be purchased and installed, which are not included with the cross-connect system.

2.9 FIBER SPLICING

Outside plant fiber splices shall be fusion type and made along the fiber route where indicated. The splices shall exhibit an insertion loss not greater than 0.2 dB. All splice measurements shall be made at 1300 nm,

plus or minus 5 nm. All splices shall be mounted in splice trays (See Section 2.6.1 for size and type). The number of cable splices shall not be increased.

2.10 TEST PLAN

Contractor shall submit for approval, a test plan (SD-88) showing when and how each system will be tested, 30 days in advance of actual testing. A testing validation procedure shall also be submitted, which shall be itemized to the extent that will permit recording the tested parameters including space for sign-off witnessed by the Contracting Officer's Technical Representative.

The test schedule shall be submitted to the Contracting Officer's representative for approval, 30 days prior to the start of testing.

2.11 TEST RESULTS

The Contractor test results shall be submitted for approval in accordance with Section 01330, "Submittal Procedures" no later than ten (10) working days after the completion of each type test. Test forms are included at the end of this section.

2.12 SPARE MATERIAL FOR CROSS-CONNECT TERMINAL FACILITIES

In addition to the materials required to install the high density cross-connect system as described in the drawings and specifications, the contract shall also include additional materials to provide capability for operations personnel to perform future cross-connects of unterminated fibers. This shall include the following items: (1) additional 6 fiber jumper bundle cables (one additional reel [1 km minimum] of both single mode and multi-mode cable); (2) additional re-enterable mechanical splices or connectors (10% surplus beyond total number required for testing); (3) additional tools required to perform the re-enterable mechanical splice and/or the cross-connection operation between fibers in the CXT facilities (two additional sets of all necessary tools shall be provided).

2.13 RE-ENTERABLE MECHANICAL SPLICES

All fiber splices within the CXT high density cross-connect systems shall be made using a re-enterable mechanical splice. Acceptable splices shall include the GTE Fastomeric Mechanical Splice, the AT&T CSL Mechanical Splice, the Norland UVC Mechanical Splice, the 3M High Density Fiber Optic Connector, or approved equal. The term "re-enterable" shall be taken to mean that the splice is designed to have the fibers being spliced, removed and re inserted without degrading optical performance or physically damaging the fibers. Splices which are designed to permanently secure the fibers within the splice shall not be used.

The splices shall be designed to allow a 250 micron fiber (the outside plant fiber) to be spliced to a 900 micron tight buffered fiber (the CXT jumper bundle assembly fiber). The re-enterable mechanical splice shall be used to perform test cable splices as described in other portions of this specification.

2.14 INDOOR CABLE (OFNR/OFNP)

OFNR (Optical Fiber Nonconductive Riser) cable shall be used in buildings where fiber cable runs longer than 50 feet15.2 m, and outside conduit are necessary, and where cable is routed between building floors or routed within non-air handling areas.

OFNP (Optical Fiber Nonconductive Plenum) cable shall be used in buildings where fiber cable runs longer than 50 feet15.2 m, and outside conduit are necessary, and cable is routed through plenum or air handling areas.

Both OFNR and OFNP cable shall be as defined in NFPA 70.

OFNR/OFNP cables shall contain materials which give the cables suitable strength to allow them to be placed in ducts and cable tray systems, along with other communication cables.

2.15 CABLE RACKING MATERIALS

Cable racking shall be used inside buildings to support fiber optic cables. The racking material shall be channel type, rather than trough type, and shall be constructed of steel material. The rack sections shall consist of tubular side bars spaced on 12"305 mm centers. All fittings and connecting hardware required for bends, offsets, and junctions shall be compatible with the rack sections.

PART 3 EXECUTION

3.1 GENERAL

Cable construction work shall be performed by construction personnel who are experienced in placing cables in conduit, cable trays, and underground duct systems.

Fiber optic cable splices, terminations and testing shall be made by journeymen cable splicers who are experienced in splicing and terminating, and one year in testing fiber optic cables.

Each individual who is to perform fiber optic cable splicing may be required to perform a minimum of one acceptable sample splice and termination. Sample splices and terminations shall not be incorporated in the job. The qualifications for all personnel to perform splicing and terminations and testing shall be submitted to the Contracting Officer for approval, 30 days prior to start of installation.

3.2 CABLE

Cables shall be provided in continuous lengths as required to accomplish the required installation without splices from termination to termination, except where field splices are specifically shown on the contract drawings. If the Contractor deems it necessary to change or eliminate any splice, or make any other than those shown on drawings, the Contractor shall submit reasons therefore, and the proposed splicing techniques to the Contracting

Officer for approval. The splices, if approved, shall be provided at no additional cost to the Government. All cables shall be terminated with appropriate connectors and associated hardware at all locations, except when indicated otherwise on the contract drawings.

3.3 FIBER SPLICES

The completed fusion type splice shall be covered with a protective sleeve (heat shrink type or approved equal) to restore the protective properties of the fiber coating and buffering. Deviations to the splice location and pulling plan will be permitted, upon approval by the Contracting Officer.

All fiber colors shall be continuous from end to end. No switching or staggering of color scheme within the cable at splice points shall be allowed. Exception to this shall take lace when splicing one 144-fiber cable to two 72-fiber cables. In all cases, fibers shall be spliced according to the cable number and fiber count. See contract drawings for details. Fibers shall be spliced in numerical order according to the fiber counts as shown on the drawings, with multi-mode fibers identified first and single mode fibers at the end.

The cables shall be brought out of the manhole into a controlled environment to perform the fiber fusion splice operation. The splice shall be completed by returning the cable to the manhole and routing the cable around the manhole interior in a neat and orderly manner, such that the excess cable does not impede future entrance and utilization. The cable is to be secured at regular intervals.

3.4 WORK IN MANHOLES AND CABLE VAULTS

The Contractor shall be responsible for ensuring that safe operating procedures are followed, work equipment is adequate, and personnel have received proper training. All atmospheric tests will be conducted by others, prior to Contractor personnel entering a manhole or vault. Safety equipment will be inspected and approved by an authorized representative of the Contracting Officer.

Use of torches, furnaces or other open flame, heat generating devices or smoking shall not be permitted in manholes.

Open manholes shall be protected by fences, railings, signs, flags, or lights, as applicable. Body static electricity that may have accumulated shall be discharged to ground prior to personnel contact with manhole covers. Removal of manhole covers shall be performed by two men using hooks and employing proper lifting techniques. All manhole covers in the immediate vicinity of the duct system where work is to be performed shall be removed to permit adequate ventilation.

Each time work is begun, excessive water shall be removed or pumped from the manhole vault or duct run, as required, prior to personnel entrance.

A manhole entry permit shall be required for every manhole entry. This permit will be issued by Environmental Health personnel employed by NASA or one of its contractors.

Vapor tests shall be performed to ensure that the presence of explosive gases is below dangerous concentration levels (less than 25 percent by volume).

Above environmental tests shall be performed each time work is started or at the initial crew change, and shall be repeated in a time interval not to exceed 8 hours. If prolonged forced ventilation is required, the time interval for additional tests shall not exceed 2 hours.

Two persons shall be present during manhole operations: one man enters the manhole, the other shall remain outside. The outside man shall be equipped with a communication device to call for help if necessary, as specified by OSHA 1710.2B.

Blowers shall be operated continuously while work is being performed and until work is completed.

Environmental tests must indicate atmosphere is safe prior to personnel entry.

Blowers or ejectors shall not be placed in the manhole or cable vault, but shall be located on the surface at a distance not less than 5 feet from the open manhole or cable vault, to assure a safe operating atmosphere.

Ladders of the proper length and type (wood or fiberglass) shall be used for entry into manholes.

The Contractor shall locate all engine driven equipment downwind from manholes.

3.5 CABLE PLACEMENT

The contract drawings show the general location of the cables and equipment to be placed. The Contractor shall be responsible for surveying the installation to determine obstacles to installation and the exact locations for cables and equipment to be installed. Any conditions that would preclude installation of cables and equipment in the location shown on the contract drawings shall be immediately reported to the Contracting Officer.

Maintain a minimum of 305 mm12 inches between communication cabling and power conductors.

3.5.1 Securing Cable

Immediately after cable placement, a permanent identification tag as indicated on drawings shall be attached to visible cable sections. The cables shall be checked to ensure that the markings are intact.

Cables and equipment shall be supported and secured as shown on the contract drawings. Where the specific method of support is not shown, adequate supports and fasteners shall be used to secure cables and equipment in position. Metallic supports and fasteners shall be hot-dipped galvanized steel in manholes and vaults having metallic cable racks, and

shall be non-metallic material in manholes and vaults having non-metallic racks. All cables shall be routed along the interior sides of manholes.

Two or more cable hooks or cable rack arms are required per manhole.

Clamps and Ty-Raps shall be used as necessary to properly secure the cable.

3.5.1.1 Bending

Caution shall be used when bending cable to avoid kinks or other damage to the sheath. The bend radius shall be as large as possible, with a minimum of 10 inches. Minimum radius shall be increased when necessary to meet cable manufacturer's recommendation. Cables shall not rest against the edge of the duct conduit mouth, the 30 inch manhole opening or other sharp edges.

Unless otherwise approved, the cable shall be pulled and spliced in the manner and at the locations specified in the drawings.

3.5.1.2 Pulling

Cable shall be pulled into the duct system using equipment designed for this purpose. This equipment shall have the capability to continuously monitor the cable pulling tension. Submit SD-30 on this equipment and include calibration data. The cable pulling tension shall not exceed 600 pounds.

Cable pulling using vehicles is not permitted.

A sufficient number of trained personnel with 2-way radio communications equipment shall be employed, to ensure proper installation of the cable.

Pulling lines shall be attached to both cable ends when cable is destined for bi-directional pull, and fitted with factory-installed pulling eyes as shown in AFTO 31W3-10-12, Figure 10-34. Exception to this may be implemented for pulling 144-fiber cable in 1 inch inner duct; submit pulling plan as required SD. Cables not equipped with a pulling eye shall have the pulling line attached to the cable end by means of a cable grip, installed as shown in AFTO 31W3-10-12, Figure 10-34. Core hitches shall not be used.

Cable reels shall be located and aligned so that the cable is paid out from the top of the reel into the duct or conduit in a long, smooth bend, without twisting. Cable shall not be pulled from the bottom of the reel. A cable feeder guide of proper dimensions shall be used at the mouth to guide the cable into the duct or conduit.

Rigging shall be set up at the pulling end so that the pulling line and cable exit on a line parallel with the duct or conduit, to prevent either from rubbing against the edge or mouth. Cable ends shall not be pulled around sheave wheels. When the sheave or pulley cannot be positioned to obtain sufficient cable end slack for proper racking and splicing with the pulling line attached to the end of the cable, a split cable grip may be used to obtain the necessary slack.

3.5.1.3 Lubricant

Adequate pulling lubricant, Hydra-lube F-100, manufactured by Arnco, Westlake, Ohio or approved equal shall be used to minimize pulling tension and prevent sheath damage when pulling cables into ducts and conduits. Lubricant shall be applied to the cable sheath with a lubricator. When pulling has been completed, the exposed cable ends shall be wiped clean of lubricant. All lubricant spills shall be cleaned up immediately.

Lubricants shall be certified by the lubricant manufacturer to be compatible with and intended for use with plastic-sheathed cables. Soap and grease type lubricants are prohibited.

All equipment and the pulling set shall be carefully checked to minimize interruptions once pulling begins. When possible, the cable shall be pulled without stopping, until the required amount of the cable has been placed. If for any reason the pulling operation must be halted before the pull is completed, the tension of the pulling line shall not be released. When pulling is resumed, the inertia of the cable shall be overcome by increasing the tension in small steps a few seconds apart until the cable is in motion. The cable shall be paid from the top of the reel by rotating the reel in the feed direction at the rate of pull. The cable shall not be stripped off the reel by pulling.

3.5.1.4 Damage and Defects

It shall be the Contractor's responsibility to ensure, by means of a tension monitoring device, that the cable pulling procedures being used do not exceed the maximum pulling tension, as specified by cable manufacturer.

The cable shall be carefully inspected for sheath defects or other irregularities as it is paid out from the reel. If defects are detected, pulling shall stop immediately and the cable section shall be repaired or replaced at the discretion of the Contracting Officer. A system of communications, visual or otherwise, shall be maintained between pulling and feed locations so that pulling can be stopped instantly, if necessary.

When making pull-throughs, a man shall be used in the intermediate manhole(s) to guide the cable into the next duct section. Proper rigging shall be used in the intermediate manhole(s) to keep the pulling line and cable aligned with the exit duct, to prevent the line or cable from rubbing against the edge of the duct. Cables in pull-through manholes shall be set up and racked before the cable ends in adjacent manholes are set up and racked. The Contractor shall exercise caution during the pulling operation to avoid excess slack and prevent kinking or any damage to the cable.

Cable ends pulled into manholes, vaults, or terminal locations that are not to be racked or otherwise permanently positioned immediately shall be tied in fixed positions to prevent damage to the cables and provide adequate working space.

3.5.1.5 Duct Seal

Inner duct in which cable is placed shall be sealed with insta-foam duct seal or approved equal to prevent damage to the cable sheath and to prevent the entrance of dirt or water into the inner duct. All unused inner duct installed on this project shall be sealed at both ends by using Aeroquip part #IP1052W, or approved equal.

3.5.2 Cabling Installation in Cable Trays

Communication cables shall not be installed in the same cable tray with AC power cables.

Cables placed in cable trays shall be installed in a neat and orderly manner and shall not cross or interface other cables, except at break-out points.

Cables in vertical trays shall be individually retained with Ty-Rap straps or equal, a maximum of 6 feet on center.

3.5.3 Cable Delivery

The replacement cable reels shall be delivered to the Government as directed by the Contracting Officer.

3.6 SEQUENTIAL CABLE RECORD

The sequential cable markings along the cable prior to and after each end of splice point, shall be recorded on the sequential cable form and submitted for approval. A sample form is included at the end of this section.

3.7 SPLICE CLOSURE OPERATIONS

Prior to encapsulation of all completed fiber splices, the Government will inspect each splice and approve workmanship.

Encapsulating compound shall be placed between inner and outer closures only under well ventilated conditions. Breathing of vapors shall be avoided. Safety glasses or goggles and impervious or non-penetrable gloves are required. Eye and skin contact shall also be avoided.

Filling compounds within the cable jacket may be removed by using "Hydrasol" cleaner, made by American Polywater Corporation, Stillwater, Minn., or approved equal, or other product recommended by the specific cable manufacturer.

3.8 GROUNDING SYSTEMS

Metallic cabling shall be grounded at each termination point or as indicated on the contract drawings.

3.9 TESTING

All test equipment, test procedures, and testing techniques shall be specified in the acceptance test plan and will require approval prior to execution. Tests shall be conducted by the Contractor in accordance with the approved Test Plan. The purpose of this testing is to verify that the installed fiber optic cable system meets all specified attenuation and bandwidth requirements and is capable of being used for its intended purpose. Field tests shall be witnessed by the Government technical representative. As stated elsewhere in the contract, the Government technical representative shall be given twenty (20) working days notice, prior to performing each test.

Test results shall be submitted for approval. Manufactured or assembled products or equipment shall be tested as indicated, and the results submitted to the Contracting Officer for approval, prior to shipment to the site. Additional tests shall include tests of the reeled cable, as well as pre-connectorized cable assemblies. All test leads shall be of the same type, same specification and manufactured by the same firm as that of the multi-fiber cable, or as otherwise stated by the test equipment manufacturer. The Contractor shall perform OTDR tests on each fiber after splicing operations. Final installation tests shall be made end-to-end. Test shall be made on all fibers in both directions.

3.9.1 Test Plan

The Contractor shall prepare a test plan which provides a detailed outline of all testing to be accomplished. The test plan shall address whether cladding modes have been stripped prior to testing, source wavelength (peak), spectral width full width/half maximum (FWHM), mode structure, fiber end preparation, and bandwidth measurements of fiber links both greater and less than 1 km. The test plan shall include, as a minimum, a schedule of when tests will be performed (relative to installation milestones), specific test procedure that will be used, a list of test equipment that will be used (manufacturer, model number, range, resolution accuracy) and shall conform to the specified requirements of other sections of this specification.

3.9.2 Test Results

Each test sheet shall have a sign-off blank for the Contractor, as well as the contract technical representative. Copies of the completed test forms or test results shall be delivered according to the shop drawing to the shop drawing procedures.

The Contractor shall maintain an accurate test record during all field tests. Samples are attached at the end of this section. Use of these sample formats are not mandatory, but any Contractor-developed format for recording test data shall be submitted for approval as part of the test plan. Submit tests as directed by the requirements of the following sections.

3.9.3 Factory Tests

Manufacturing or factory tests shall be made and submitted to the Contracting Officer for approval, prior to shipment of material to the site.

3.9.3.1 Multi-Fiber Cable Tests

Specification 79K28125, Revision K, shall be used as the basis for optical and mechanical performance test requirements. Mechanical bend radius, tensile strength, crush resistance and impact resistance test required by 79K28125, Revision K, shall be performed on each lot or design type of cable. The results of these tests together with the numerical aperture, attenuation and bandwidth tests of each reel of cabled fiber shall be submitted in accordance with the referenced EIA Standards. See sample test form at the end of this section.

3.9.3.2 Pre-Connectorized Cable Assembly

Attenuation of each assembly shall be made and submitted for approval prior to shipment to the site. The method of testing shall be in accordance with 79K28125, Revision K, and shall be included in the acceptance test plan. See sample test form at the end of this section.

3.9.4 Tests During Installation

The Contractor shall perform Optical Time Domain Reflectometer (OTDR) tests during cable installation splice operations. Fiber alignment shall be made according to the OTDR read out to minimize the loss as the fusion splice is completed. A sample form is included at the end of this section.

A 1 km (minimum) fiber delay line is required between the OTDR and the first connector and after the far end connector. Splices not conforming with the maximum attenuation requirements shall be reworked to conform.

If after three attempts, the specified value is not obtained, then a NASA Engineering Evaluation is required before further splicing may commence. OTDR values for all splices shall be recorded in the presence of the technical representative.

The recorded values shall be submitted to the Contracting Officer for approval within one (1) work day of said record being made.

3.9.5 Installation Completion Tests

After terminations and splices have been completed, each fiber shall have an OTDR fiber trace made for the entire span, including a 1 km (minimum) fiber delay line before the first connector and after the last connector. This test shall be performed in both directions. These OTDR records shall be submitted to the Contracting Officer for approval within fourteen (14) calendar days. Final acceptance will be based on the final end-to-end attenuation and bandwidth test. Final acceptance of pre-connectorized cable assemblies shall be based on OTDR measured patch panel loss after installation.

All OTDR Final Acceptance Test Data shall be submitted on 3.5"89 mm diskettes. The Contractor shall use an OTDR having this capability. The Contractor shall provide three (3) sets of this data.

The Contractor shall also provide three (3) sets of legally registered and licensed PC-based OTDR-emulation software (including documentation) which is compatible with the OTDR used during testing. The software requirement will be waived by the Government if one of the following OTDR/software combinations is used for the testing.

a.	ANRITSU	MW9040B MX3602B	OTDR OTDR Emulation Software - 1st Edition (1994)
b.	TEKTRONIX TFP2	OTDR TFP2	 Fiber Master Trace Analysis Package (FMTAP) Emulation Software - Version 2.00 (1993) Fiber Master Utility Disk - Version 1.02 (1993)
c.	Laser Precision Corp.		TD 350 Version 2.29 (3/26/96) PC-3000 OTDR Emulation Software
d.	Siecor (Corning)		OTDR 2001-PC OTDR Emulation Software V1.10 (5/26/92)

3.9.6 Final Acceptance Tests

Final acceptance tests shall be made after all other tests are performed and approved. Final acceptance tests measure attenuation and bandwidth of installed fibers. Sample forms are included at the end of this section. Completed forms shall be submitted to the Contracting Officer for approval within three (3) working days of test.

3.9.6.1 End-to-End Attenuation Test

Attenuation shall be measured at the 1300 nm and the 1550 nm wavelength of both the single mode and the multi-mode fiber using the insertion loss method, performed in each direction. The measurement requires the use of a stable light source and a light meter, both with a designated jumper cord whose far end connector is the type an make of the installed fiber being measured. The light source jumper cord shall wrap around a 1/2 inch diameter mandrel a minimum of five (5) times. The light source cord shall be connected to the light meter cord by means of a Bulkhead Assembly/Fee Through Adaptor (same type as system to be measured) and the meter reading shall be set to zero or used as the reference loss. The light source shall then be connected to one end of the fiber under test and the light meter to the other end, and the meter reading recorded. If the meter had a reference loss, it must be subtracted from the recorded test reading to determine the loss. Fibers used during test shall meet the same specifications as the fibers under test.

The measured loss shall not exceed the calculated loss. The calculated loss (Lc) shall be shown as:

Lc(multi-mode, 1300 & 1550) shall be equal to
lt(1 dB/km)+n1(.2dB)+n2(.5dB)

Lc(Single mode, 1300 & 1550) shall be equal to
lt(.5dB/km)+n1(.2dB)_n2(.5dB)

Where lt is the length in kilometers of the fiber to be tested, n1 is the number of splices in the length to be tested, and n2 is the number of connector halves in the length to be tested.

End-to-end attenuation tests shall be performed at both 1310 nm and 1550 nm on both multi-mode and single mode fibers. The multi-mode fibers shall be judged acceptable only on the basis of the 1310 nm window tests; the 1550 nm tests shall be performed for record purposes only. The single mode fibers shall be judged acceptable on the basis of both windows, i.e., each fiber must meet the requirements for both 1310 nm and 1550 nm.

3.9.6.2 End-to-End Bandwidth Test (Multi-Mode Only)

The end-to-end bandwidth shall be measured utilizing frequency domain method. The bandwidth shall be measured in both directions on all multi-mode fibers and measurements shall be recorded. The bandwidth at -3 dB optical power of each optical fiber in the cable shall be a bandwidth length product greater than 1 GHz-km within a peak optical emissive region of 1280-1330 nm. This test shall be made at the completion of the testing. See sample test form at the end of this section. The calculated bandwidth (BWc), with Gamma equal to 1, shall be shown as:

For fiber length less than 1 km;
BWc shall be greater than or equal to 1 GHz

For fiber length greater than 1 km;
BWc shall be greater than or equal to 1GHz-km/lt

Where lt is the length in kilometers of the fiber to be tested.

3.9.6.3 Acceptance Tests of Loopback Fibers

Fiber cable installed within the CXT facilities shall be subject to the same acceptance tests as described above.

Fibers which are looped back within the CXT facilities shall be tested end-to-end through the CXT and back to the originating facility. When testing through the CXT's, the re-enterable mechanical splices required here shall be treated in the end-to-end attenuation budget as separate field splices, i.e., a total of 0.2 dB shall be allowed in the budget for the CXT's mechanical splice connector loss.

3.10 TEST EQUIPMENT

The test equipment used for verifying installation testing shall be

calibrated by a certified testing company within three (3) weeks of use, and meet the following requirements:

3.10.1 Optical Time Domain Reflectometer (OTDR)

Operating wavelengths: 1,300 plus or minus 20 nanometers

Attenuation Range (one way): Minimum 15 dB at 1,300 nm

Attenuation Resolution: 0.01 dB

Accuracy: plus 0.5 dB

Display: OTDR's shall have digital readout capability and shall have a means of providing a permanent record of the fiber trace on 3.5"89 mm diskettes.

OTDR PC Software: See 3.9.5

3.10.2 Attenuation Measurement Test Set

An attenuation measurement test set shall consist of an optical power meter and an optical power source. The attenuation measurement test set must be traceable to NBS standards for stable optical source. The meter may be analog or digital. The following requirements shall apply:

Operating wavelengths: 1,300 plus or minus 10 nanometers

* The Government will provide the Contractor with a power meter and light source to complete testing at the 1550 nm window for multi-mode fiber only.

Attenuation Range: at least 30 dB or better at 1,300 nm

Attenuation Resolution: 0.01 dB

Accuracy: The accuracy of the attenuation measurement test set shall be plus or minus 5 percent.

The optical source shall be capable of coupling sufficient power into the fiber so that the light received at the meter is within the meter detectability limits.

3.10.3 Bandwidth Measurement Equipment

All bandwidth measurement equipment shall meet the following requirements:

a. Operating wavelengths: 1,300 plus or minus 10 nanometers

b. Bandwidth Range: minimum 1000 megahertz

c. Bandwidth Resolution: 1 megahertz

d. Accuracy: The accuracy of the bandwidth measurement equipment shall be plus or minus 0.5 megahertz.

e. Measurement Method: Swept Frequency

3.11 TABLES

SAMPLE DATA FORM, PARAGRAPH 3.6

SEQUENTIAL CABLE MARKINGS

CONTRACT NAME/NUMBER:_____

FROM BLDG:_____ TO BLDG./END POINT_____

LENGTH _____ km. CABLE NUMBER_____

BUILDING MANHOLE	LOCATION	READING	DISTANCE
	START POINT		km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
			km
	END POINT		km
TOTAL (START TO END)			km

TEST CONDUCTOR:_____ DATE:_____

CONTRACTING OFF. REP._____ DATE:_____

SAMPLE DATA FORM, PARAGRAPH 3.10.6.2

FACTORY CABLE DATA (REELED)

CONTRACT
NAME/NUMBER:_____

CABLE MFG.:_____ DATE:_____

ADDRESS:_____ REEL NO._____

CABLE IDENTIFICATION:_____ REEL LENGTH_____km

FIBER CA NO	TUBE AND FIBER COLOR	BANDWIDTH (MHz-km) 1300nm	ATTENUATION (dB/km)		NUMERICAL APERTURE
			1300nm	1500nm	

TEST CONDUCTOR:_____ DATE:_____

CONTRACTING OFF. REP._____ DATE:_____

SAMPLE DATA FORM, PARAGRAPH 3.10.6.1

END-TO-END ATTENUATION TEST

CONTRACT
NAME/NUMBER:_____

BLDG LOC._____ TO_____ FROM_____

CABLE NO._____ NO. CONNECTORS_____ NO. SPLICES_____

CALCULATED ATTENUATION:_____dB TEST REFERENCE LOSS:_____dB

TEST WAVELENGTH:_____

FIBER NO.	COLOR TUBE/ FIBER	FIBER UNDER TEST (dB)	NET LOSS (dB)	FIBER NO.	COLOR TUBE/ FIBER	FIBER UNDER TEST (dB)	NET LOSS (dB)

TEST CONDUCTOR:_____ DATE:_____

CONTRACTING OFF. REP._____ DATE:_____

SAMPLE DATA FORM, PARAGRAPH 3.10.6.2

END-TO-END BANDWIDTH TEST

CONTRACT
NAME/NUMBER:_____

FROM BLDG.:_____ TO BLDG./END POINT_____

LENGTH_____km CABLE NUMBER_____

CALCULATED BANDWIDTH BWc_____

FIBER NO.	COLOR TUBE/FIBER	BNDWDTH @1300nm	GHz -km	FIBER NO.	COLOR TUBE/FIBER	BNDWDTH @1300nm	GHz -km

TEST CONDUCTOR:_____ DATE:_____

CONTRACTING OFF. REP._____ DATE:_____

SAMPLE DATA FORM, PARAGRAPH 3.10.3.2

PRE-CONNECTORIZED CABLE ASSEMBLY FACTORY DATA

CONTRACT
NAME/NUMBER:_____

CABLE
MFG.:_____

ADDRESS:_____

ASSEMBLY
IDENTIFICATION:_____

CONNECTOR TYPE:_____km LOT NO._____

ASSEMBLY NUMBER	ATTENUATION (dB/km) 1300 nm	ASSEMBLY NUMBER	ATTENUATION (dB/km) 1550nm

TEST CONDUCTOR:_____ DATE:_____

CONTRACTING OFF. REP.:_____ DATE:_____

SAMPLE DATA FORM, PARAGRAPH 3.10.4

FIELD TERMINATION SPLICE RECORD

CONTRACT
NAME/NUMBER:_____

TEST LOCATION:_____ CABLE NUMBER:_____

SPLICE LOCATION:_____ LENGTH TO SPLICE:_____km

LENGTH TO END OF FIBER:_____km

FIBER NO.	TUBE COLOR/ FIBER COLOR	SPLICE ATTEMPT/ LOSS db 1 2 3	FIBER NO.	TUBE COLOR/ FIBER COLOR	SPLICE ATTEMPT/ LOSS db 1 2 3

TEST CONDUCTOR:_____ DATE:_____

CONTRACTING OFF. REP.:_____ DATE:_____

-- End of Section --